# XBeach skillbed report

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**XBeach skillbed report**

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# Chapter 1

# Introduction

For the WTI2017 project, one of the deliverables is a new version of the XBeach model, intended for use as an advanced dune safety assessment model. This report describes the requirements for a 1 dimensional advanced dune safety assessment model and tries to show that XBeach meets those requirements. The latter is done by comparing the model results to measurements, either taken during laboratory experiments or in the field.

# Chapter 2

# Requirements for advanced dune safety assessment

An advanced dune safety assessment is performed when a detailed assessment is considered unsuitable for a certain location or stretch of dune coast. In general, the morphological behaviour at those locations is significantly influenced by physical processes that are lacking in the detailed assessment model (a 1-dimensional profile model), hence the need for a more in-depth advanced assessment. This is the case for approximately 40% of the dutch coastline. The most common causes are listed below:

**Flat profile slopes** Very flat beach and foreshore slopes are often gentler than the resulting profile of the detailed safety assessment, so no dune erosion is predicted. However, in practice the presence of long waves does cause dune erosion.

**Irregular profiles** Profiles containing pronounced irregular features like banks or gullies present a problem for the detailed safety assessment model, which imposes a prescribed shape on the final profile.

**Hybrid sea defenses** These sea defenses consist partly of sand and partly of a hard structure. (for instance sea walls, dune (foot) revetments, dikes dith dunes in front).

**Hard objects** In particular at coastal cities there are often hard objects present on or in front of the sandy sea defense, while not functionally being part of the sea defense. These objects can however have an influence on the morphological behaviour of the sandy sea defense during storm conditions.

**Variating storm surge** XBeach can be forced with storm surge levels and wave boundary conditions that vary in time.

In the table below, the functional requirements to the WTI2017 version of XBeach are summarized and translated into physical processes the model should be able to resolve succesfully.

*Table 2.1: Translation of functional requirements into physical processes*

| Functional requirement | Physical process |
|---|---|
| Dune erosion | hydrodynamics, morphodynamics |
| Gentle slopes | long waves |
| Irregular profile shapes (banks & gullies) | process based model (no prescribed final profile) |
| Structures & objects | hard layers, scour holes |
| Realistic storm forcing | time varying storm surge & wave forcing |

The WTI2017 version of XBeach is supposed to be a solution to the above mentioned problems. To be able to show that XBeach is capable of doing so, the model results will be compared to large and small scale laboratory measurements and field data. Before doing this, the required functionalities have to be translated in to measurable physical aspects, on which the comparison will be made. This is shown in the table below, including the availability of measurements for comparison on each aspect.

*Table 2.2: Overview of relevant physical processes in dune safety assessment*

| Physical aspect | Experimental (small scale) | Experimental (large scale) | Field observations |
|---|---|---|---|
| **Hydrodynamics** | | | |
| Water levels | | ✓ | |
| Wave heights | | ✓ | |
| Velocities | ✓ | ✓ | |
| **Morphology** | | | |
| Erosion volume | ✓ | ✓ | ✓ |
| Erosion profile | ✓ | ✓ | ✓ |
| Sediment concentration | | ✓ | |
| Hard layers/structures | ✓ | ✓ | ✓ |
| Scour holes | | ✓ | |

# Chapter 3

# 1D Hydrodynamics

Morphodynamics start with hydrodynamics. In this chapter the hydrodynamic results of XBeach are discussed. All tests are run without the morphological module and the analsysis is focussed on the wave propagation and transformation computed by XBeach.

First, two analytical solutions are reproduced by XBeach. Subsequently, a laboratory experiment is discussed.

## 3.1 Long wave propagation

The purpose of the this test is to check if the NSWE numerical scheme is not too dissipative and that it does not create large errors in propagation speed.

A long wave with a small amplitude of $0.01m$ and period of $80s$ was sent into a domain of $5m$ depth, grid size of $5m$ and a length of $1km$. At the end, a fully reflecting wall is imposed. The wave length in this case should be $\sqrt{9.81 \cdot 5} \cdot 80 = 560m$. The velocity amplitude should be $\sqrt{g/h} \cdot A = \sqrt{9.81/5} \cdot 0.01 = 0.014m$. After the wave has reached the wall, a standing wave with double amplitude should be created.

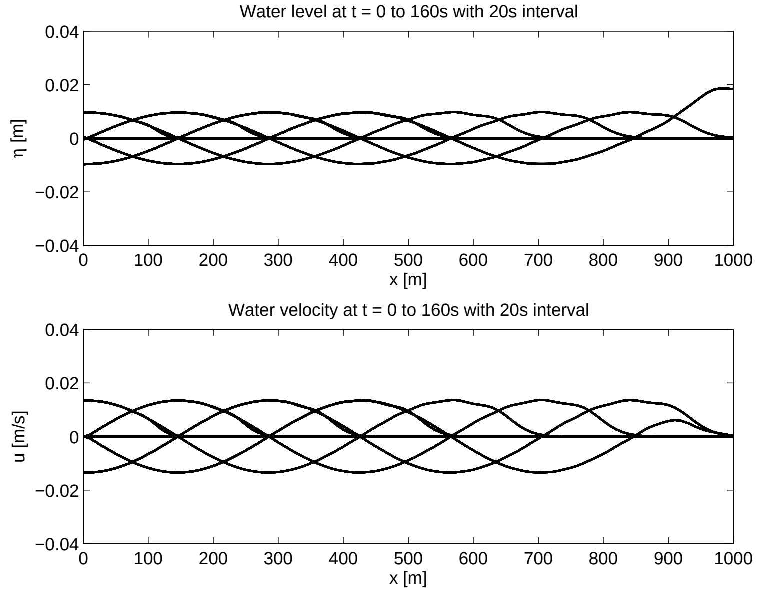

*Figure 3.1: Water levels and velocities from the start of the experiment until the wave just reaches the end of the flume*

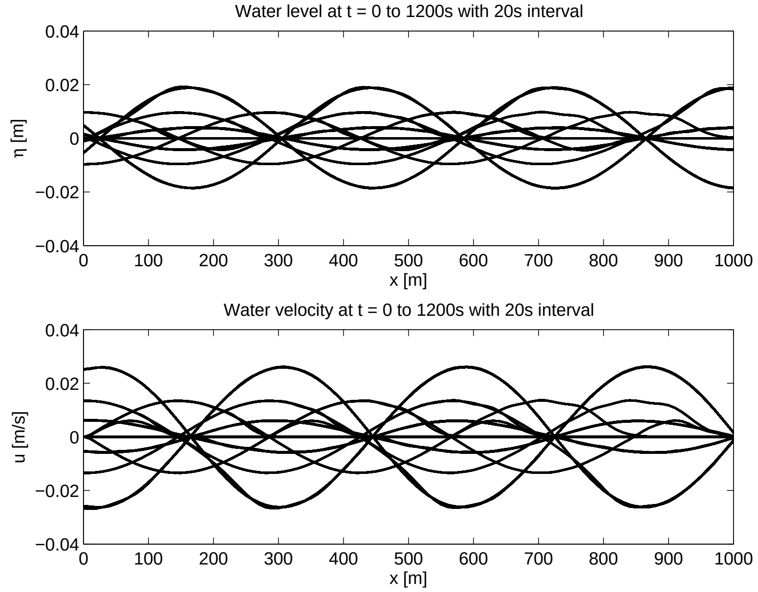

*Figure 3.2: Snapshots of water levels and velocities showing a standing wave pattern*

## 3.2 1D wave runup (analytical solution)

The purpose of this test is to check the ability of the model to represent runup and rundown of non-breaking long waves. To this end, a comparison was made with the analytical solution of the NSWE by Carrier and Greenspan (1958), which describes the motion of harmonic, non-breaking long waves on a plane sloping beach without friction.

A free long wave with a wave period of 32 seconds and wave amplitude of half the wave breaking amplitude ($a_{in} = 0.5 \cdot a_{br}$) propagates over a beach with constant slope equal to $1/25$. The wave breaking amplitude is computed as $a_{br} = 1/\sqrt{128}\cdot\pi^3 \cdot s^{2.5} \cdot T^{2.5} \cdot g^{1.25} \cdot h_0^{-0.25} = 0.0307m$, where s is the beach slope, $T$ is the wave period and $h_0$ is the still water depth at the seaward boundary. The grid is non uniform and consists of 160 grid points. The grid size $\Delta x$ is decreasing in shoreward direction and is proportional to the (free) long wave celerity $(\sqrt{g \cdot h})$.The minimum grid size in shallow water was set at $\Delta x = 0.1m$.

To compare XBeach output to the analytical solution of Carrier and Greenspan (1958), the first are non-dimensionalized with the beach slope $s$, the acceleration of gravity $g$, the wave period T, a horizontal length scale $L_x$ and the vertical excursion of the swash motion $A$. The horizontal length scale $L_x$ is related to the wave period via $T = \sqrt{{L_x}/{g \cdot s}}$ and the vertical excursion of the swash motion A is expressed as: $A = a_{in} \cdot {\pi}/{\sqrt{0.125 \cdot s \cdot T \cdot \sqrt{{g}/{h_0}}}}$

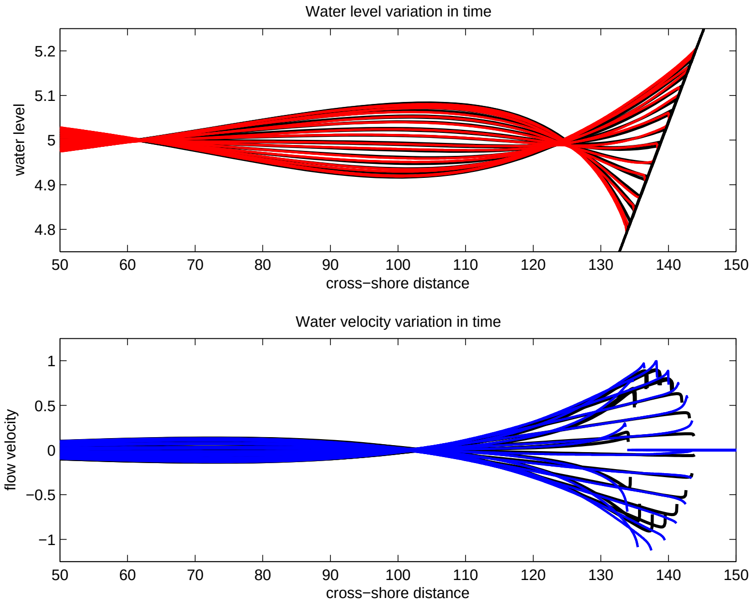

*Figure 3.3: Snapshots of water level and velocity*

## 3.3 High- and low-frequency wave transformation

Boers (1996) performed experiments with irregular waves in the physical wave flume at Delft University of Technology with a length of 40 meters and a width of 0.8 m. The flume is equipped with a hydraulically driven, piston type wave generator with second-order wave generation and Active Reflection Compensation. Boers ran waves over a concrete bar-trough beach, which was modelled after the Delta Flume experiments. He ran three different irregular wave conditions, but in this report we will focus on case 1C, a Jonswap spectrum with $H_{m,0} =$ 0.1m and $T_p = 3.3$s. The surface elevation was measured in 70 locations shown in Figure 3.4.

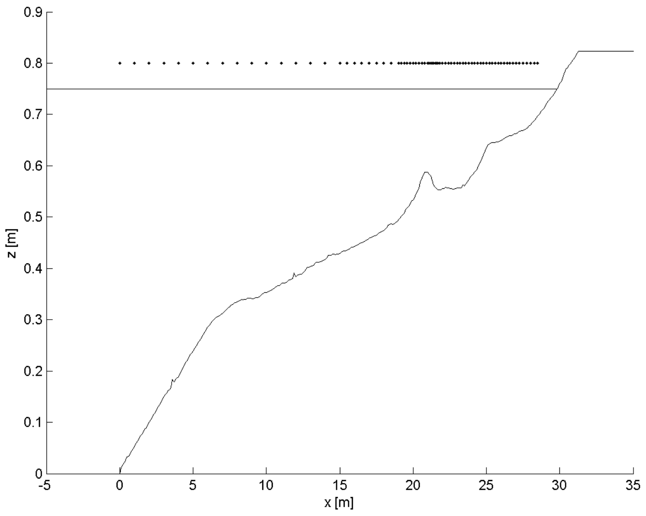

*Figure 3.4: Locations of surface elevation measurements*

The comparison between the model and the data for the wave height transformation of the short waves and the long waves (defined as waves with a frequency greater than $f_p/2$ and less than $f_p/2$, respectively) is shown in Figure 3.5.

The red dashed line and triangles indicate the short wave height transformation. The blue line and circles indicate the mean (steady) set-up. The dotted red line and upside-down traiangles indicate the total (incoming and reflected) low frequency wave.

The observational data is separated into incoming and reflected long wave components using an array of wave gauges (Bakkenes, 2002) and the numerical data has been separated into two components using co-located surface elevation and velocity information.

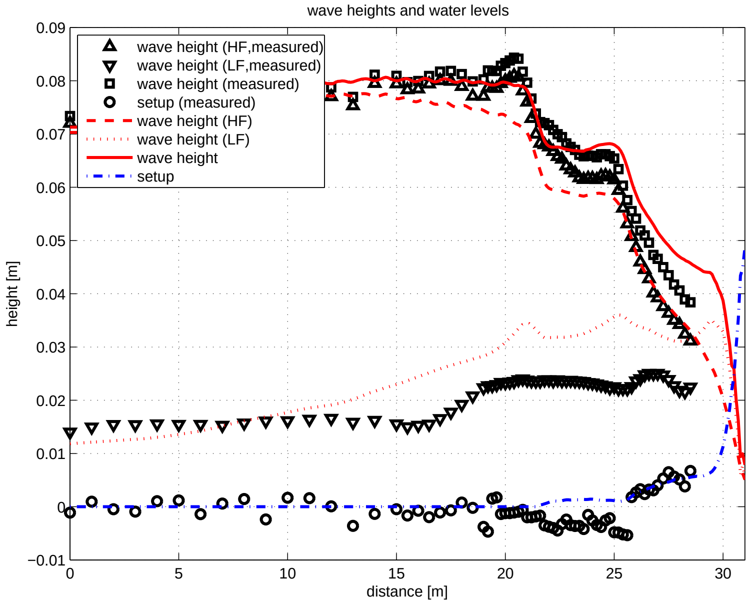

*Figure 3.5: Wave height transformations during Boers 1C experiment*

# Chapter 4

# Dune erosion

In this chapter, the performance of XBeach is compared to results obtained from physical model tests performed in a variety of laboratory facilities and field measurements. Many of those tests are part of fundamental research to dune erosion and other morhpological processes. Research took place on different scales, mainly depending on the size of the facility used. The chapter seperately discusses small scale laboratory tests (with a depth scale factor $n_d$ between 85 and 15), large scale laboratory tests ($n_d$ between 6 and 2, appraching prototype) and field measurements.

As described in the previous chapter, the relevant skill parameters for accurately predicting dune erosion are the post-storm cross-shore profile, the total eroded volume and the sediment concentration near the water line. For all scales mentioned above, an example will be described in more detail, after which an overview of the performance of all available tests will be presented.

## 4.1 Small scale laboratory tests

The example test depicted in figure Figure 4.1 was part of a series of experiments performed during 1976 and 1977 in the Wind Flume of Laboratory De Voorst in The Netherlands(Van de Graaff, 1976). During the experiments, depth scales of 84, 47 and 26 were used, the test under consideration has a depth scale of 26.

As can be gathered from the figure, the model results follow the erosion profile closely and closely reproduce the retreat of the dune crest, resulting in a high skill score.

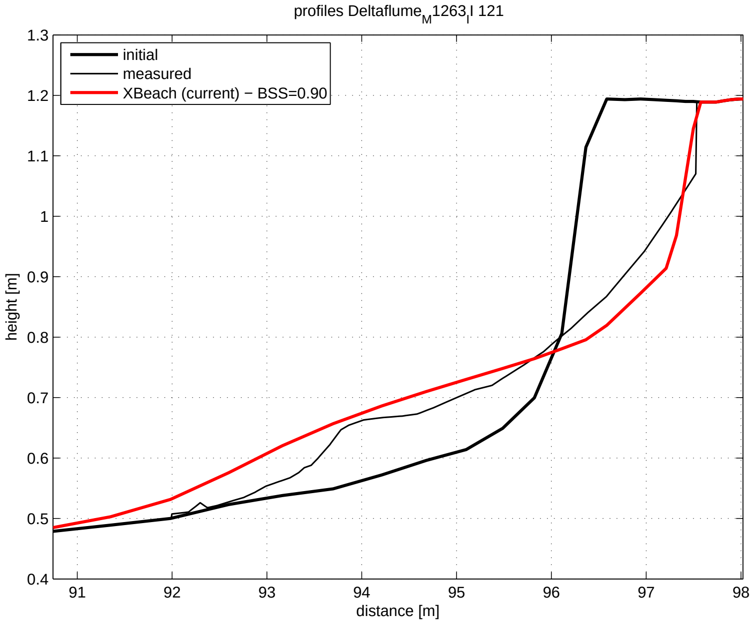

*Figure 4.1: Final profile of test 121*

The majority of the small scale laboratory tests perform reasonable to good, as can be seen in figure Figure 4.2.

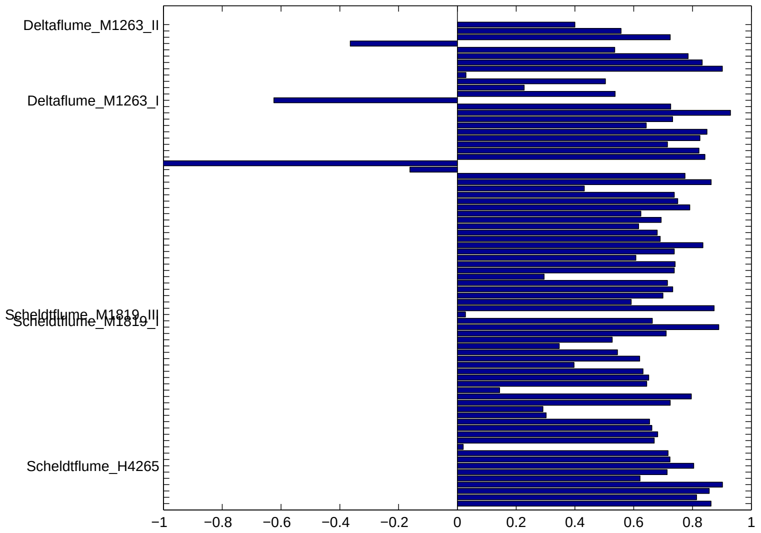

*Figure 4.2: Skill scores for small scale laboratory tests*

## 4.2 Large scale laboratory tests

The profile depicted in figure Figure 4.3 belongs to the 2006 experiments performed in the Deltaflume in the Netherlands (Van Gent et al., 2008).

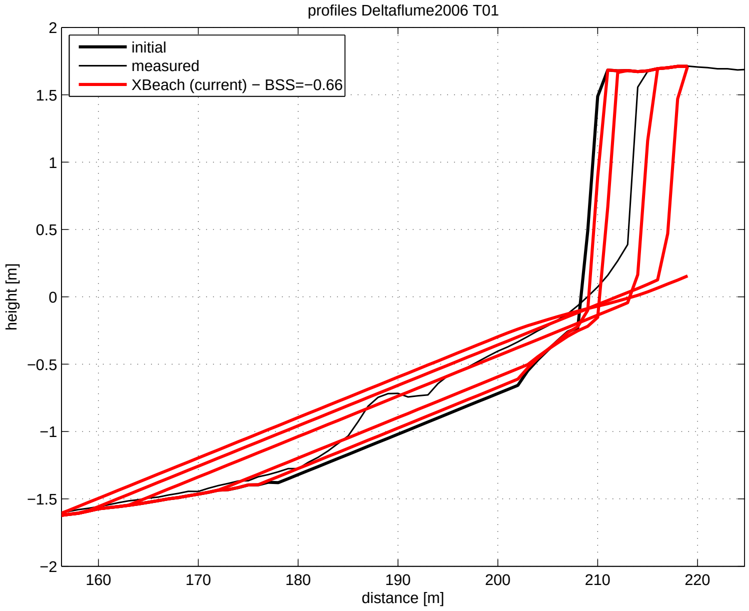

*Figure 4.3: Final profile of test T01*

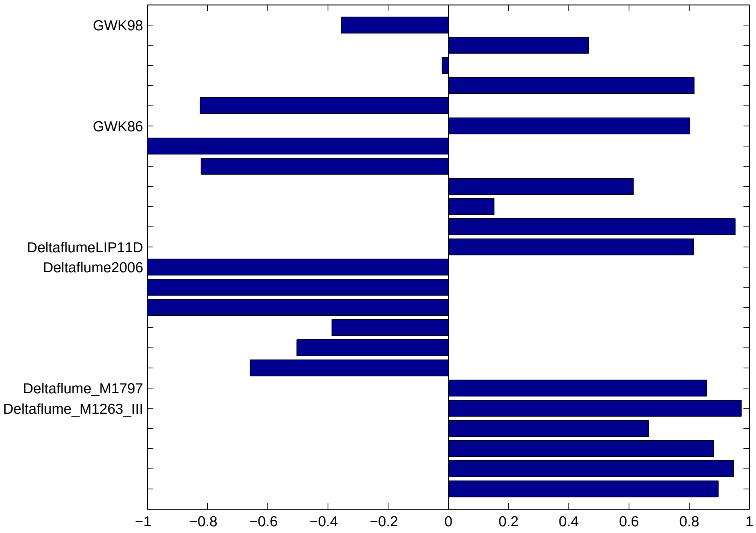

*Figure 4.4: Skill scores for large scale laboratory tests*

## 4.3 Field measurements

In figure Figure 4.5, results of an XBeach simulation are compared to measurements from the storm surge that occurred on the night of January 2nd, 1976.

The profile development in the model results closely follows that of the measurements. The same can be said for the other field cases, leading to good skill scores in figure Figure 4.6.

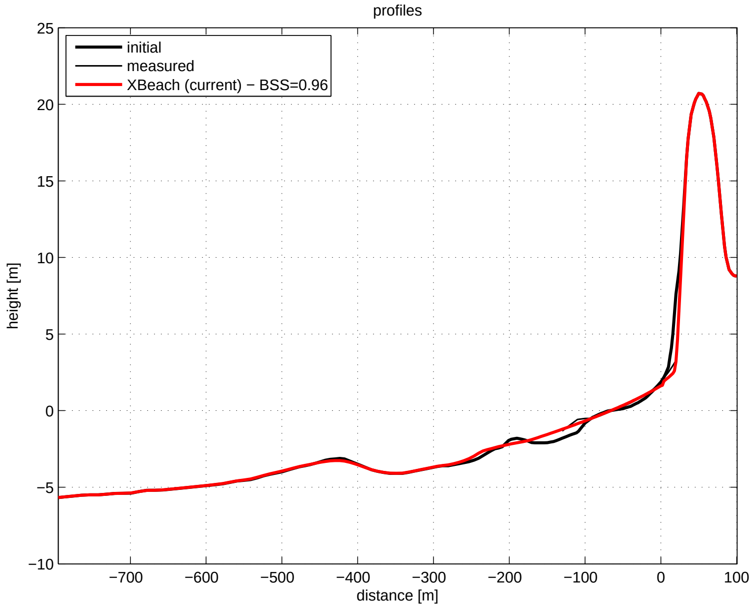

*Figure 4.5: Profile of raai 6050*

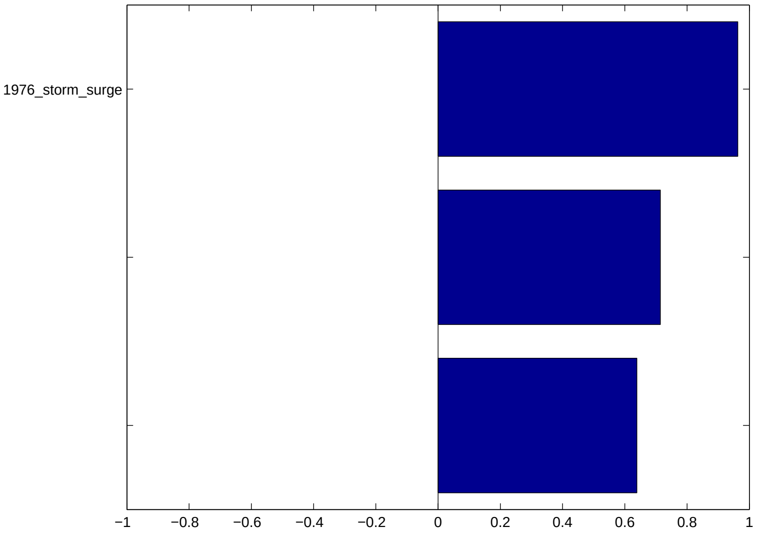

*Figure 4.6: Skill scores for large scale laboratory tests*

# Chapter 5

# Morphological laboratory tests with revetments

The profile depicted in figure Figure 5.1 is part of a series of large scale experiments ($n_d = 5$) with revetments of different heights (Steetzel, 1987). Both the scour hole in front of the revetment as well as the erosion above the revetment are well represented in the simulation results. The amount of sediment deposition in seaward of the scour hole is slightly underestimated.

*Figure 5.1: Final profile of test 3*

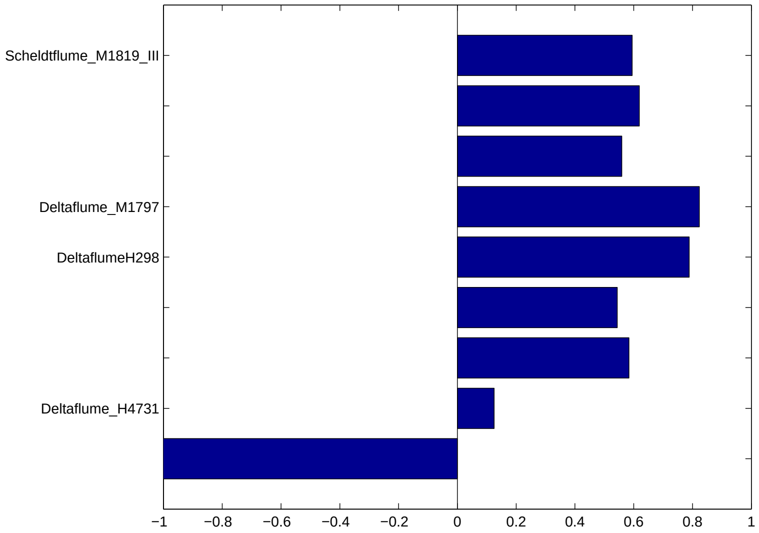

Figure 5.2: Skill scores for laboratory tests with revetments

# Chapter 6

# Model comparison

In this chapter, XBeach is compared to results obtained from other models. The comparisons are currently focussed on the DUROS+ and D++ (Vellinga, 1986; Delft Hydraulics, 2006; Deltares, 2010) models that are used for the detailed assessment of dunes along the Dutch coast. Comparisons with other models like DurosTA (Steetzel, 1993) are made throughout the report and are not discussed specifically in this chapter at the moment.

## 6.1 Field applications

In this section, DUROS+ (Vellinga, 1986; Delft Hydraulics, 2006) and D++ are (Deltares, 2010) compared with XBeach based on field applications. Comparisons are made based on erosion volumes and retreat distances, since these are the main parameters of interest in dune safety assessment.

### 6.1.1 Retreat distances JARKUS

In this test, retreat distances obtained from DUROS+ and XBeach using a selection of JARKUS profiles characteristic for the Dutch coast are compared (den Heijer et al., 2011). The comparison is presented in Figure 6.1. The retreat distance as defined as the horizontal distance between the NAP+5m contour and the erosion point. The erosion point is defined as the first diversion point between the pre-storm and post-storm profile, when going from the land side in seaward direction. Diversion is considered as a vertical difference of more than 5cm.

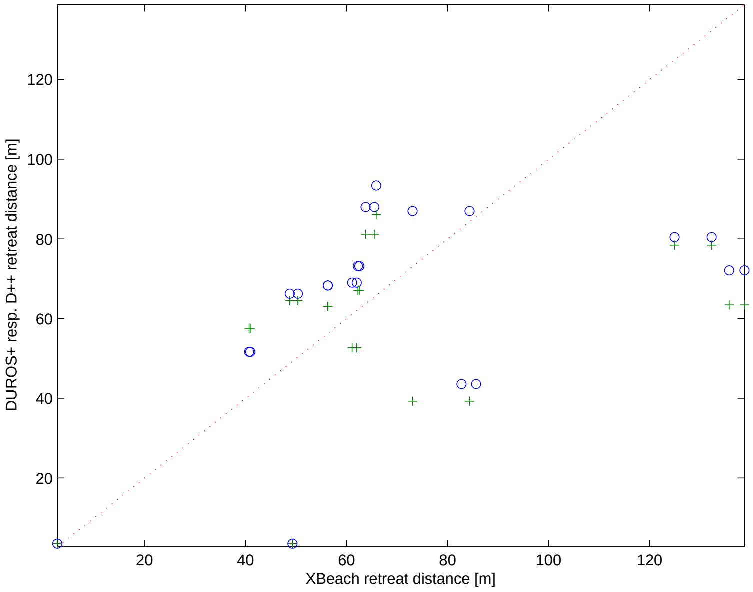

*Figure 6.1: Scatter plot of retreat distances obtained from XBeach and DUROS+*

# Chapter 7

# 2D features

# Chapter 8

# Conclusion

# Chapter 9

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